chamber, after said first voltage changing process, said second voltage changing process, and said third voltage changing process,

wherein a voltage changing time t_4 during said fourth voltage changing process is set as follows relative to the resonance frequency T_c of the pressure wave generated in said pressure generating chamber:

$0 < t_4 < T_c/2$;

wherein a time interval between a start time of said second voltage changing process and a start time of said fourth voltage changing process is set substantially half the length of the resonance frequency T_c of the pressure wave generated in said pressure generating chamber.

REMARKS

Claims 18-22 are all the claims presently pending in the application. Claims 18-22 have been amended to more particularly define the invention. Claims 18-22 are independent.

Attached hereto is a marked-up version of the changes made to the claims by the current Amendment. The attached page is captioned "**Version with markings to show changes made.**" These amendments are made only to more particularly point out the invention for the Examiner and not for narrowing the scope of the claims or for any reason related to a statutory requirement for patentability.

Applicant also notes that, notwithstanding any claim amendments herein or later during prosecution, that Applicant's intent is to encompass equivalents of all claim elements.

Claims 18-22 stand rejected under 35 U.S.C. § 103(a) as being obvious over Chang (EP 0947325) in view of Sakai (U.S. Patent No. 5,933,168.

This rejection is respectfully traversed in the following discussion.

I. THE CLAIMED INVENTION

The claimed invention is directed to a method for driving an ink jet recording head. The method includes applying a driving voltage to an electro-mechanical converter to deform the electro-mechanical converter to thereby change a pressure in the pressure generating chamber filled with ink, thus ejecting ink droplets through a nozzle in communication with the pressure generating chamber.

The driving voltage includes a first voltage changing process, a second voltage changing process and a third voltage changing process. The first voltage changing process is for applying a voltage in a direction that increases a volume of the pressure generating chamber. The second voltage changing process is for applying a voltage in a direction that reduces the volume of the pressure generating chamber. The third voltage changing process is for applying a voltage in a direction that increases the volume of the pressure generating chamber again.

The voltage changing times t_2 and t_3 during the second and third voltage changing processes are set so as to have such lengths as shown below, relative to a resonance frequency T_c of a pressure wave generated in the pressure generating chamber: $0 < t_2 < T_c/2$; and $0 < t_3 < T_c/2$. Lastly, the method further includes providing a nozzle with an about 20 to about 30 μm opening diameter to eject said ink droplets in a size of about 5 to about 25 μm size.

This configuration provides a method for driving an ink jet recording head having a nozzle opening of about 20 to 30 μm which enables fine ink droplets having a smaller size (for example, about 5 to 25 μm) from a nozzle to be stably ejected even at a high frequency. The pressure wave generated by ejecting a fine ink droplet is most efficiently restrained from reverberating by setting the time interval between a start time of the second voltage changing process and a start time of a fourth voltage changing process, equal to or shorter than half of the resonance frequency Tc of the pressure wave in the pressure generating chamber. This is because the pressure wave will have a phase opposite to that of the pressure wave generated by the second voltage changing process and this will efficiently cancel the latter pressure wave.

II. THE PRIOR ART REJECTION

The Examiner alleges that the Sakai reference would have been combined with the Chang reference to form the claimed invention. Applicant submits, however, that these references would not have been combined and even if combined, the combination would not teach or suggest each and every element of the claimed invention.

Applicant submits that these references would not have been combined as alleged by the Examiner. Indeed, the references are directed to different matters. Specifically, the Chang reference is directed to reducing a volume of an ink drop without lowering the traveling speed of the ink drop by following the contraction of the pressure generating chamber with an expansion step in such a manner that the velocity of the trailing end of the ejected ink drop is substantially zero near the nozzle orifice (col. 2, lines 32 - 51).

In contrast, the Sakai reference is specifically directed to stably ejecting ink drops having a size smaller than the nozzle opening by timing the contraction of the pressure generating chamber to coincide with the moment when the movement of the central region of the meniscus begins to reverse to produce an inertial stream that acts intensively upon the central region of the meniscus (Abstract). Therefore, one of ordinary skill in the art would not have been motivated to combine these references since these references are directed to completely different matters.

Further, even assuming arguendo, that one of ordinary skill in the art would have been motivated to combine these references, even if combined, the combination would not teach or suggest each and every element of the claimed invention.

The Chang reference discloses a method for driving an ink jet printhead. In particular, the Chang reference appears to disclose following a contraction of the pressure generating chamber with an expansion step in such a manner that the velocity of the trailing end of the ejected ink drop is substantially zero near the nozzle orifice (col. 2, lines 32 - 51). As admitted by the Examiner, the Chang reference does not teach or suggest providing a nozzle with an about 20 to about 30 μm opening.

The Sakai reference does not remedy the deficiencies of the Chang reference. The Sakai reference discloses driving method to stably eject ink drops having a size smaller than the nozzle opening by timing the contraction of the pressure generating chamber to coincide with the moment when the movement of the central region of the meniscus begins to reverse to produce an inertial stream that acts intensively upon the central region of the meniscus (Abstract). While the Sakai reference appears to disclose nozzle openings with diameters of 51 to 56 μm (col. 2,

line 7), 32 μm (col. 6, line 42 and col. 11, lines 23-24) and 30 μm (col. 8, line 43). The Sakai reference does not teach or suggest providing a nozzle with an about 20 to about 30 μm opening. Therefore, the Examiner is respectfully requested to withdraw this rejection.

III. FORMAL MATTERS AND CONCLUSION

In view of the foregoing amendments and remarks, Applicant respectfully submits that claims 18-22, all the claims presently pending in the Application, are patentably distinct over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the Application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.

The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

Date: 2/3/03

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

In the claims:

Please amend claims 18-22 as follows:

18. (Amended) A method for driving an ink jet recording head, comprising

applying a driving voltage to an electro-mechanical converter to deform the electro-mechanical converter to thereby change a pressure in the pressure generating chamber filled with ink, thus ejecting ink droplets through a nozzle in communication with the pressure generating chamber, wherein said applying said driving voltage comprises:

at least a first voltage changing process for applying a voltage in a direction that increases a volume of said pressure generating chamber;

a second voltage changing process for then applying a voltage in a direction that reduces the volume of said pressure generating chamber; and

a third voltage changing process for applying a voltage in a direction that increases the volume of said pressure generating chamber again;

setting voltage changing times t_2 and t_3 during the second and third voltage changing processes so as to have such lengths as shown below, relative to a resonance frequency T_c of a pressure wave generated in the pressure generating chamber:

$0 < t_2 < T_c/2$

$0 < t_3 < T_c/2$; and

providing said nozzle with an about 20 to about 30 [40] μm opening diameter to eject said ink droplets in a size of about 5 to about 25 μm size.

19. (Amended) A method for driving an ink jet recording head, comprising:

applying a driving voltage to an electro-mechanical converter to deform the electro-mechanical converter to thereby change a pressure in the pressure generating chamber filled with ink, thus ejecting ink droplets through a nozzle in communication with the pressure generating chamber, wherein said applying of said driving voltage comprises:

at least a first voltage changing process for applying a voltage in a direction that increases a volume of said pressure generating chamber;

a second voltage changing process for then applying a voltage in a direction that reduces the volume of said pressure generating chamber;

a third voltage changing process for applying a voltage in a direction that increases the volume of said pressure generating chamber again; and

setting voltage changing times t_2 and t_3 during the second and third voltage changing processes are set to have such lengths as shown below, relative to a resonance frequency T_c of a pressure wave generated in the pressure generating chamber:

$0 < t_2 < T_c/2$

$0 < t_3 < T_c/2$; and

providing said nozzle with an about 20 to about <u>30</u> [40] μm opening diameters to eject said ink droplets in a size of about 5 to about 25 μm size, wherein a start time of said third voltage changing process is about the same as an end time of said second voltage changing process.

20. (Amended) A method for driving an ink jet recording head, comprising

applying a driving voltage to an electro-mechanical converter to deform the electro-mechanical converter to thereby change a pressure in the pressure generating chamber filled with ink, thus ejecting ink droplets through a nozzle in communication with the pressure generating chamber, wherein said applying said driving voltage comprises:

at least a first voltage changing process for applying a voltage in a direction that increases a volume of said pressure generating chamber;

a second voltage changing process for then applying a voltage in a direction that reduces the volume of said pressure generating chamber; and

a third voltage changing process for applying a voltage in a direction that increases the volume of said pressure generating chamber again;

a fourth voltage changing process for applying voltage in a direction that reduces the voltage of said pressure generating chamber, after said first voltage changing process, said second voltage changing process, and said third voltage changing process;

setting voltage changing times t_2 and t_3 during the second and third voltage changing processes so as to have such lengths as shown below, relative to a resonance frequency T_c of a pressure wave generated in the pressure generating chamber:

$0 < t_2 < T_c/2$

$0 < t_3 < T_c/2$; and

providing said nozzle with an about 20 to about 30 [40] μm opening diameter to eject said ink droplets in a size of about 5 to about 25 μm size.

21. (Amended) A method for driving an ink jet recording head comprising:

applying a driving voltage to an electro-mechanical converter to deform the electro-mechanical converter to thereby change a pressure in the pressure generating chamber filled with ink, thus ejecting ink droplets through a nozzle in communication with the pressure generating chamber, wherein said applying said driving voltage comprises:

at least a first voltage changing process for applying a voltage in a direction that increases a volume of said pressure generating chamber;

a second voltage changing process for then applying a voltage in a direction that reduces the volume of said pressure generating chamber; and

a third voltage changing process for applying a voltage in a direction that increases the volume of said pressure generating chamber again;

setting voltage changing times t_2 and t_3 during the second and third voltage changing processes are set to have such lengths as shown below, relative to a resonance frequency T_c of a pressure wave generated in the pressure generating chamber:

$0 < t_2 < T_c/2$

$0 < t_3 < T_c/2$; and

providing said a nozzle with an about 20 to about 30 [40] μm opening diameter to eject said ink droplets in a size of about 5 to about 25 μm size,

wherein the voltage waveform of said driving voltage includes a fourth voltage changing process for applying a voltage in a direction that reduces the volume of said pressure generating

chamber, after said first voltage changing process, said second voltage changing process, and said third voltage changing process,

wherein a voltage changing time t_4 during said fourth voltage changing process is set as follows relative to the resonance frequency T_c of the pressure wave generated in said pressure generating chamber:

$0 < t_4 < T_c/2$.

22. (Amended) A method for driving an ink jet recording head comprising:

applying a driving voltage to an electro-mechanical converter to deform the electro-mechanical converter to thereby change a pressure in the pressure generating chamber filled with ink, thus ejecting ink droplets through a nozzle in communication with the pressure generating chamber, wherein said applying said driving voltage comprises:

at least a first voltage changing process for applying a voltage in a direction that increases a volume of said pressure generating chamber;

a second voltage changing process for then applying a voltage in a direction that reduces the volume of said pressure generating chamber; and

a third voltage changing process for applying a voltage in a direction that increases the volume of said pressure generating chamber again;

voltage changing times t_2 and t_3 during the second and third voltage changing processes are set to have such lengths as shown below, relative to a resonance frequency T_c of a pressure wave generated in the pressure generating chamber:

$0 < t_2 < T_c/2$

$0 < t_3 < T_c/2$; and

providing said a nozzle with an about 20 to about 30 [40] μm opening diameter to eject said ink droplets in a size of about 5 to about 25 μm size,

wherein the voltage waveform of said driving volume includes a fourth voltage changing process for applying a voltage in a direction that reduces the volume of said pressure generating chamber, after said first voltage changing process, said second voltage changing process, and said third voltage changing process,

wherein a voltage changing time t_4 during said fourth voltage changing process is set as follows relative to the resonance frequency T_c of the pressure wave generated in said pressure generating chamber:

$0 < t_4 < T_c/2$;

wherein a time interval between a start time of said second voltage changing process and a start time of said fourth voltage changing process is set substantially half the length of the resonance frequency T_c of the pressure wave generated in said pressure generating chamber.